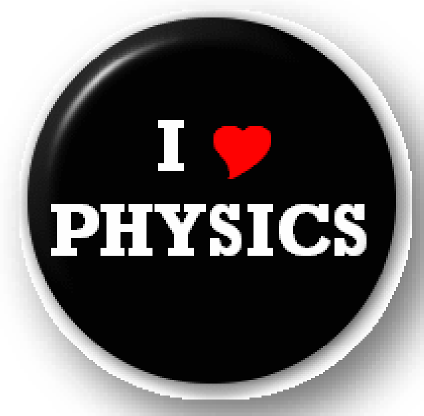
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Science Department



Physics

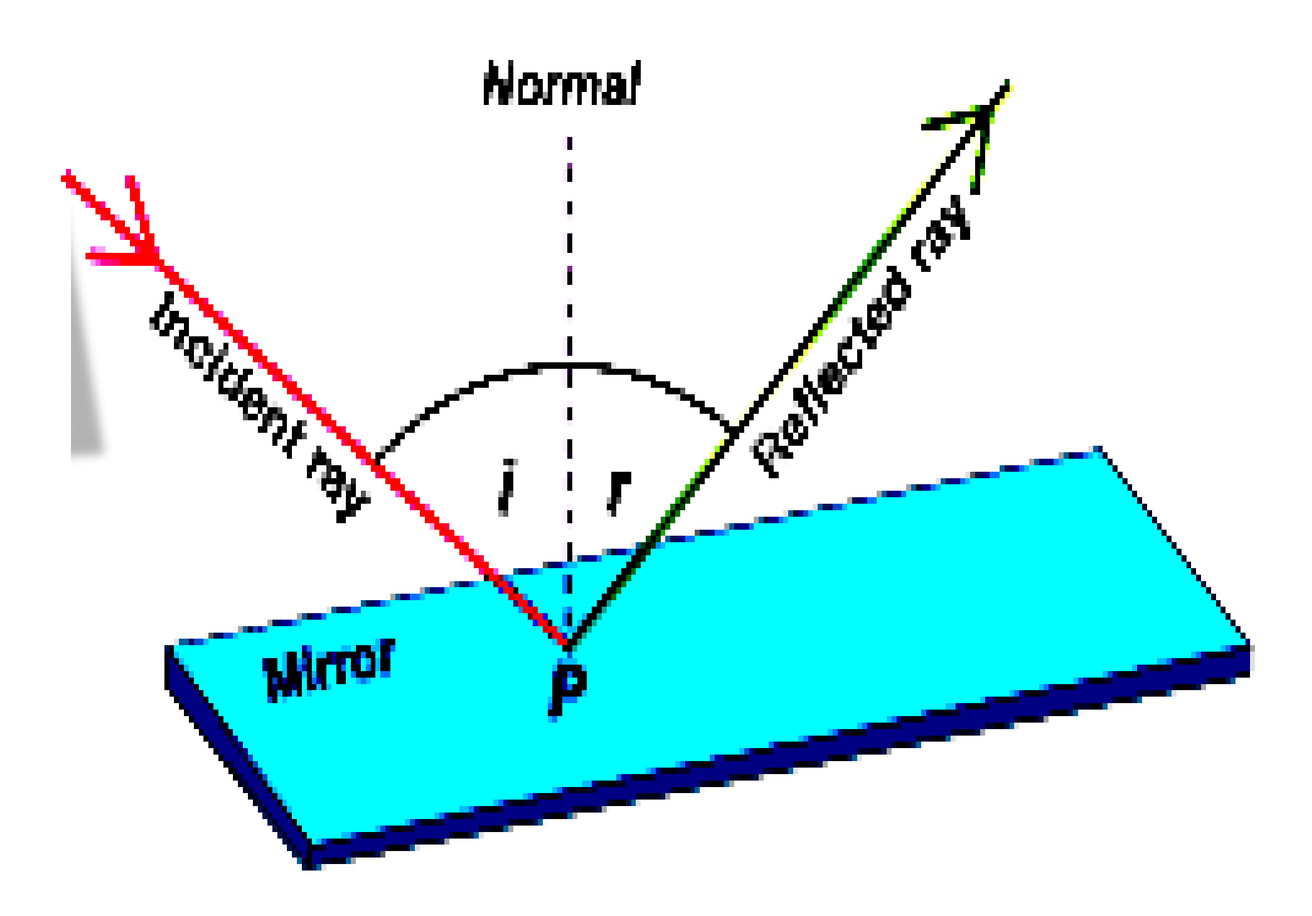
Sec.2

First term

REFLECTION OF LIGHT

2024 / 2025





Unit (1) Ch. (1) L.(1) Oscillatory motion

TYPES OF MOTION

1- TRANSLATIONAL MOTION.

2- PERIODIC MOTION.

1-Translational motion: - Has a starting point and different end point

a- In straight line

b- in curved path(projectile)

2- Periodic motion: Repeated regularly in equal intervals of time.

a- Oscillatory

b-wave

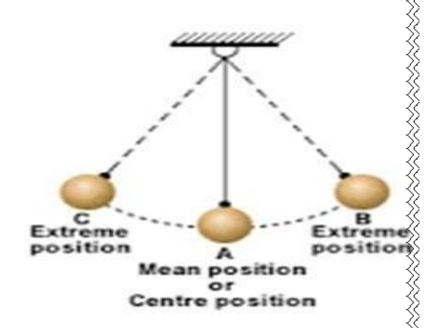
Oscillatory motion

Examples:

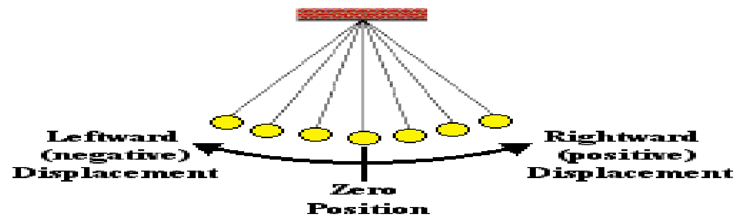
- Simple pendulum (Clock pendulum).
- Vibrating tuning fork.
- Vibrating string (violin strings).
- Plumb or bob suspended to a spring (yoyo).

Energy transformations in simple pendulum

When a pendulum moves from A to B its vertical height increases ,its potential energy increases and kinetic energy decreases.



Note: the sum. of P.E and K.E at any point remains constant.



- When a pendulum is oscillating ,the distance that the pendulum makes from the rest position at any moment is called displacement (d).

- Displacement is a vector quantity measured in meters (m).

The maximum displacement of the pendulum away from its equilibrium position is called Amplitude.

-From A B A C A is called complete oscillation .

-The time taken to make one complete oscillation is called periodic time (T).

$$T = \frac{t\ (time\ in\ second)}{N\ (no.\ of\ complete\ oscillation)}$$

T = 4 x time of amplitude.

- Frequency (f) $= \frac{\text{N (number of oscillations)}}{\text{t (time)}}$

Frequency is measured in Hertz (Hz), oscillations /second , cycles/second or second-1

The relation between the frequency and periodic time(T)

Frequency (f) = $= \frac{\text{N (number of oscillations)}}{\text{t (time)}}$ so,

$f = \frac{1}{T}$ and $T = \frac{1}{f}$

SIMPLE HARMONIC MOTION



Multiple choice questions:

1- Simple pendulum takes 0.01 s to reach the maximum displacement from the equilibrium position, so its frequency equals………………

a) 20 Hz b) 25 Hz c) 50 Hz d) 100 Hz

2- The ratio between the periodic time and the frequency of a vibrating body equals $\frac{1}{625}$ s^2 so the number of oscillations made by the body during 25 s is …………oscillations.

a) 25 b) 125 c) 425 d)625

2) Essay questions :

- What happens to the periodic time of a vibrating object when its frequency triples? Explain.

Answer: The periodic time decreases to one third of its value because frequency is inversely proportional to periodic time according to relation T= 1/*f*.

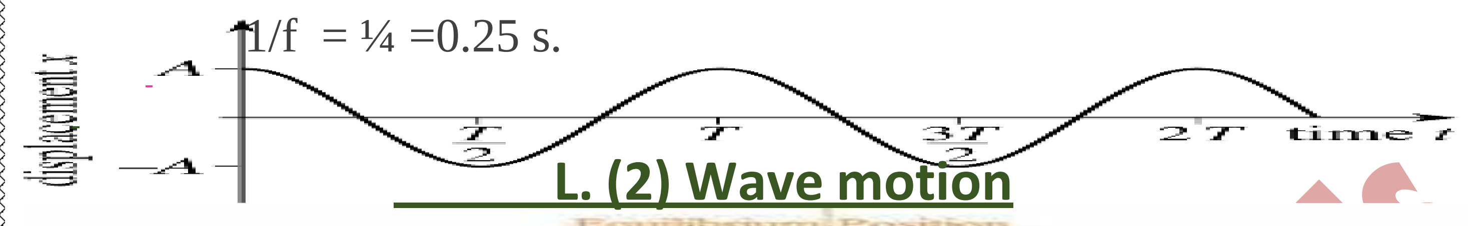
1) A wave generator produces 16 pulses in 4 s, calculate:

a) The frequency. b) The periodic time.

Answer:

Frequency (*f*) $= \frac{\text{N (number of oscillations)}}{\text{t (time)}}$ = 16 / 4 = 4 Hz.

1/f = ¼ =0.25 s.



L. (2) Wave motion

Wave: disturbance that propagates and transfer energy in the same direction of propagation.

Types of waves

Some waves can be seen such as water waves , other waves cannot be seen but we detect them such as radio and TV waves.

- Waves
  - Mechanical waves
    - Transverse waves
      - Water waves
    - Longitudinal waves
      - Sound waves
  - Electromagnetic waves
    - Transverse waves
      - Radio waves

First : Mechanical waves

A disturbance that propagates in materialistic media.

Examples:

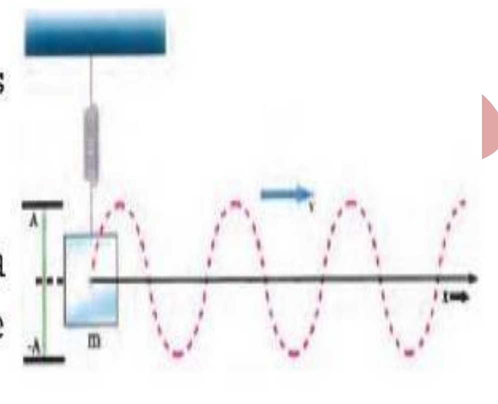
- Water waves
- Sound waves
- Waves that propagates in strings during its vibration.

Conditions of mechanical waves:

1) The presence of vibrating bodies / source (**vibrator**).
2) A kind of **disturbance** that can travel from vibrating source to the medium.
3) The presence of **medium** through which wave can propagate.

Types of mechanical waves :

First : Transverse Waves



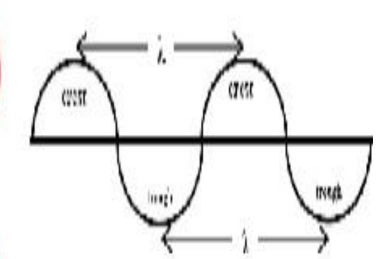
- The load makes a simple harmonic motion upwards and downwards.
- The rope makes a similar motion.
- The motion transfers along the rope in the form of a moving horizontal (→) wave at a certain velocity while the parts of the rope move vertically (↕)

Conclusion:

- When the rope vibrates upwards and downwards , the wave transfers to the rope in the form of crests and troughs.
- The direction of vibration is perpendicular to the direction of wave propagation.
- The work done by the vibrating source is stored in the form of :
  1. Potential energy. (in the pulling rope/string)
  2. Kinetic energy .(in the vibration of the rope /string)

Crest:

The position of the maximum displacement of medium particles in the **positive** direction



Trough :

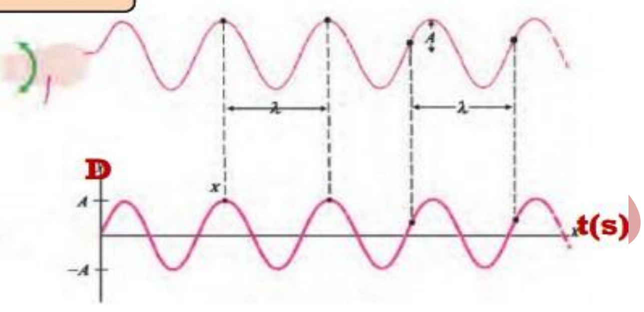
The position of the maximum displacement of medium particles in the **negative** direction

Transverse wave :

The wave in which the vibration of the medium particles is perpendicular to the direction of the wave propagation.

Graphical representation of Transverse Waves

The relation : (**displacement – distance**) or (**displacement – Time**) can be represented in by a curve in the form of **sine** wave.



Wave length :

The distance between two successive crests or two successive troughs .
Or : The distance between any crest and the successive trough.
Or : The distance between any two points having the same phase.
Or :The distance covered by the wave during one periodic time.

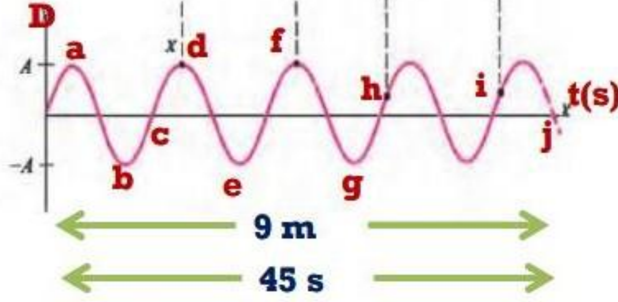
Frequency :

The number of waves that passes a certain point along the wave motion in a time 1 s.
Or: The number of wavelengths covered by the propagated wave in a certain direction in 1 s

$$wave\ length : \lambda = \frac{total\ distance}{number\ of\ waves}$$

$$Frequency : \nu = \frac{number\ of\ waves}{time}$$

From the opposite figure :



1) What do these symbols refer to :

D **A** **t** **λ**

2) How can we describe points **h** and **i** ?

3) If the displacement of the medium particles at point **a** is 5 m , what is the displacement at point **b**?

4)The distance between points **h** and **i** = …… m

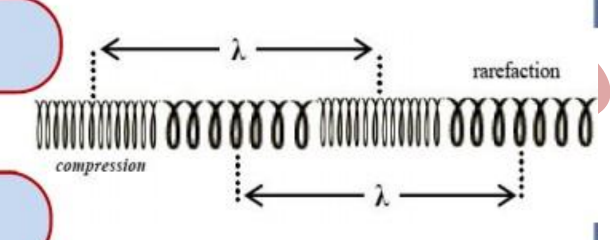
5)The frequency of the wave = …………. cycles/sec

6) The time covered at point **c** = …….. s

Longitudinal waves:

Compression:

The area in which the medium particles are close to each other.



Rarefaction:

The area in which the medium particles are far from each other.

Longitudinal wave:

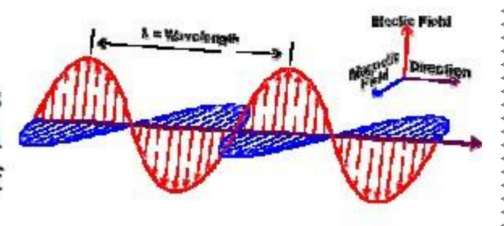
The wave in which particles vibrate along the direction of the wave propagation around their equilibrium position.

Wave length :

- The distance between the centers of two successive compressions or the centers of two successive rarefactions.
- The sum of successive compression and rarefaction

Second : Electromagnetic waves

Source :



- Originated fro the vibration of two fields ; one of them is electric field and the other is magnetic field, where both are perpendicular to each other and to the direction of wave propagation.

Electromagnetic waves

Waves originated from vibrating electric and magnetic fields having the same phase with frequency (υ) , perpendicular to each other and to the direction of wave propagation and can spread in materialistic and non-materialistic media (space).

Examples:

- Light waves
- X-rays
- Gamma rays
- Wireless waves , TV and cell phone) , where :
  - ➢ Sound or image are converted into waves received by the antenna.
  - ➢ The waves are converted into electric signals in the receiver then to sound or image .

Types :

- All electromagnetic waves are transverse waves only.

The relation between frequency , wave length , and velocity:

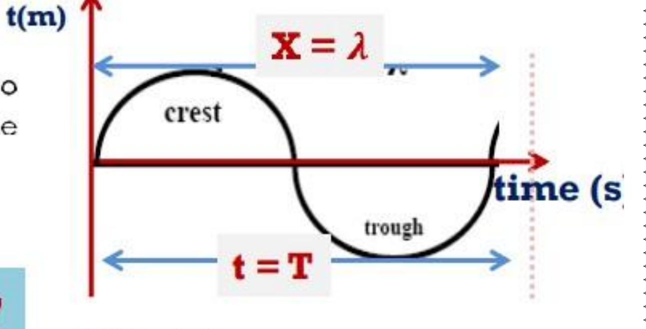
Deduction of velocity of wave propagation :

If a wave transfers at velocity (**V**) from a place to another at distance (λ) , the wave takes time equals the periodic time(**T**):

$\because V = \frac{X}{t}$ when $X = \lambda$, $t = T$ $\quad \therefore V = \frac{\lambda}{t}$

$\because \upsilon = \frac{1}{t}$

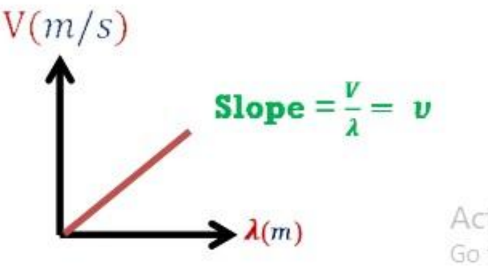
$$\therefore V = \lambda \upsilon$$



$\upsilon(Hz)$

Slope $= \lambda\upsilon = V$

$\frac{1}{\lambda}(m^{-1})$



Wave velocity :

The distance covered by the wave in one second in a certain direction.

$$V = \lambda \upsilon$$

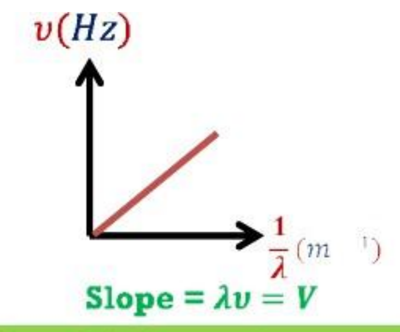
- Two waves propagate in the same medium, with different frequencies:
  - Their velocities are the same.

$$V_1 = V_2$$

$$V_1 = \lambda_1 \upsilon_1 \qquad V_2 = \lambda_2 \upsilon_2$$

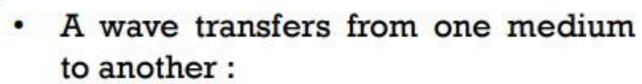
$$\lambda_1 \upsilon_1 = \lambda_2 \upsilon_2$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\upsilon_2}{\upsilon_1}$$



Slope = $\lambda \upsilon = V$

Wave length is inversely proportional to the frequency at constant velocity

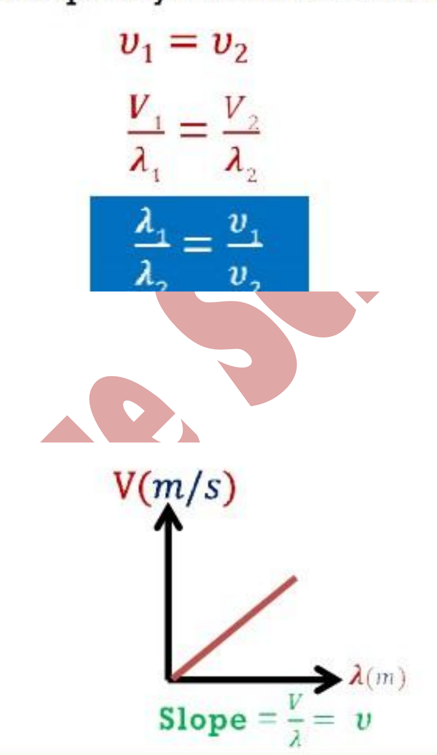


- A wave transfers from one medium to another:
  - Velocity wave length changes.
  - Frequency remains constant.

$$\upsilon_1 = \upsilon_2$$

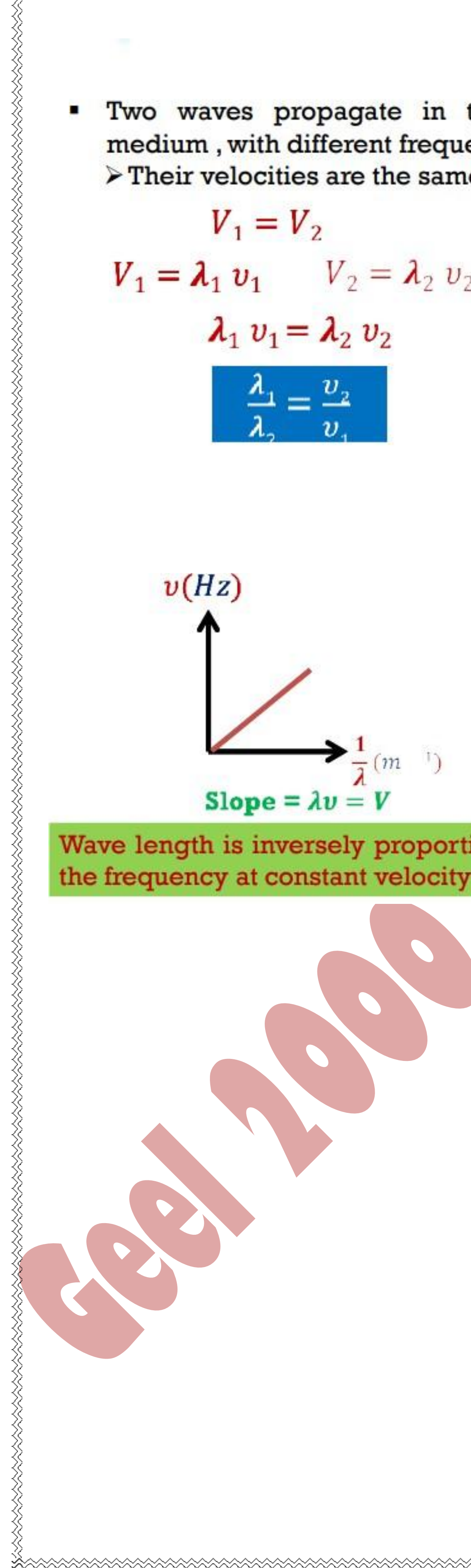
$$\frac{V_1}{\lambda_1} = \frac{V_2}{\lambda_2}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\upsilon_1}{\upsilon_2}$$



Slope = $\frac{V}{\lambda} = \upsilon$

Wave velocity is directly proportional to the wave length at constant frequency.

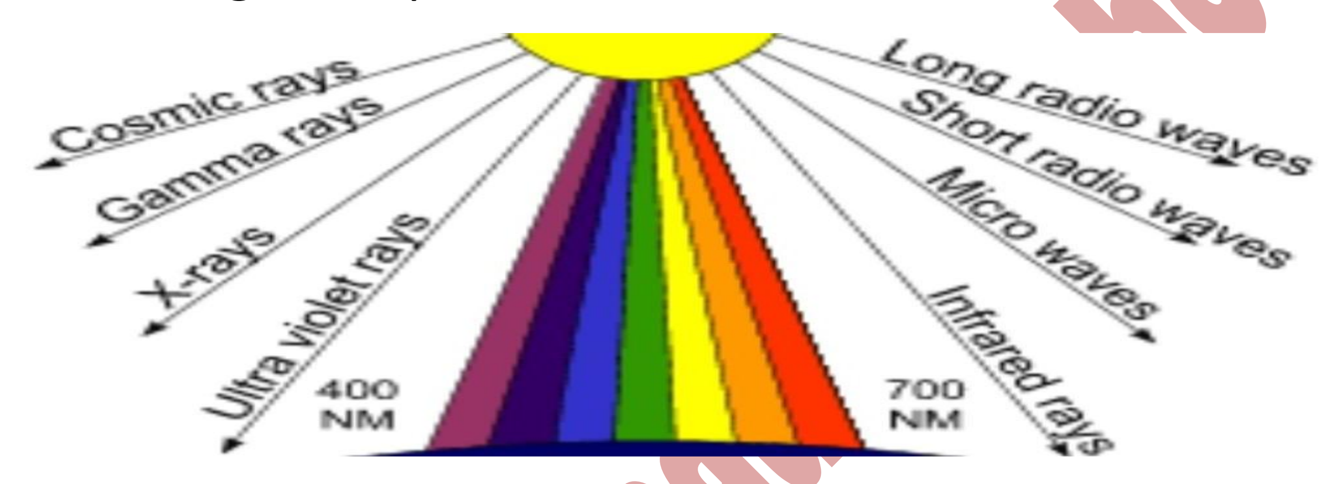


Unit (1) Ch. (2)

Properties of Light

L.(1) Propagation,reflection and refraction

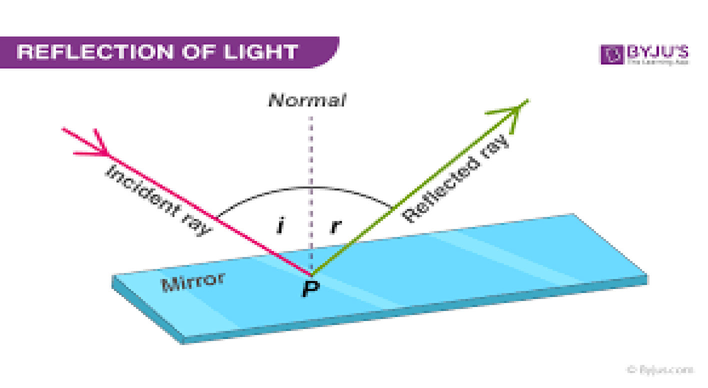
- Electromagnetic spectrum



Properties of Light waves

b) 1) Propagation. 2- Reflection. 3) Refraction.
4) Interference. 5) Diffraction.

Light reflection.



Laws of light reflection:

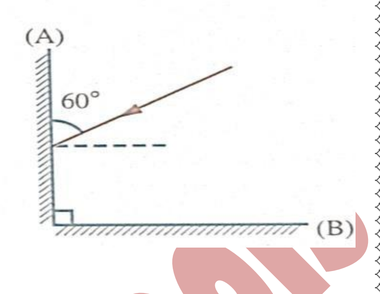
- **First law** : Angle of incidence = Angle of reflection.

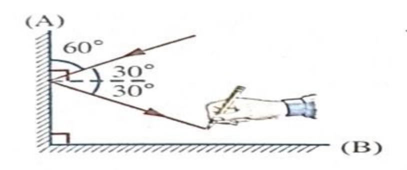
- **Second law** : The incident light ray ,the reflected light ray and the normal to the surface of reflection at the point of incidence ,all lie in one plane perpendicular to the reflecting surface.

In the opposite figure, a light ray falls on mirror (A), complete the path of the ray till it refracts from mirror (B), then calculate the value of :

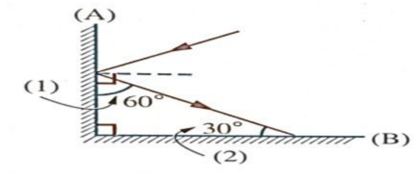
(1) The angle of reflection from mirror (A).

(2) The angle of incidence on mirror (B).





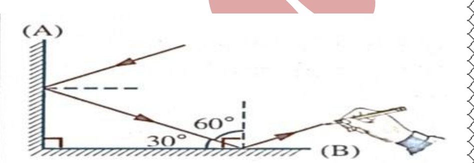
Angle of reflection from mirror (A) = angle incidence
= 90° – 60° = 30°



The angle (1) between the reflecting ray and mirror (A)
= 90° – 30° = 60°

∵ The sum of angles of triangle = 180°

∴ The angle (2) between the incident ray and mirror (B)
= 180° – (60° + 90°) = 30°

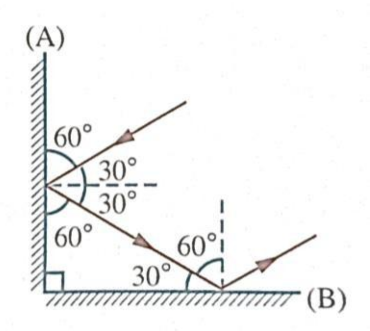


∴ The angle of incidence on mirror (B)
= 90° – 30° = 60°

Answer

(1) The angle of reflection from mirror (A) = 30°

(2) The angle of incidence on mirror (B) = 60°

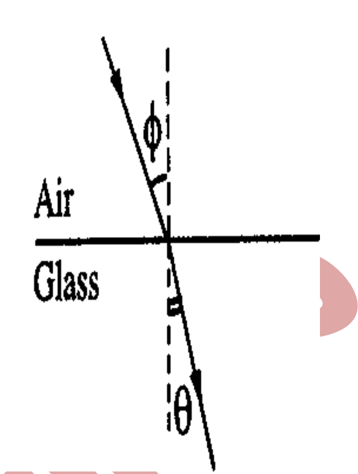


▸ **Light refraction** Change of light path when it travels from a transparent medium to another transparent medium of different optical density.

Incident ray
Normal
Angle of incidence
90°
Boundary
Substance 1
Substance 2
Angle of refraction
Refracted ray

The absolute refractive index:

$$n = \frac{\sin\phi}{\sin\theta} = \frac{c}{v} = \frac{\lambda_{(air)}}{\lambda_{(medium)}}$$



$$n = \sin\varphi / \sin\theta = c/v$$

Factors affecting the absolute refractive index:

1-The wavelength of incident ray.
2-The type of medium.
3-

The relation between relative index and absolute refractive index:

□ $n = c/v$, $v = c/n$

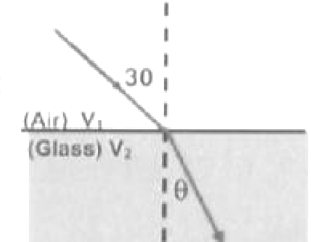
□ $v_1 / v_2 = n_2 / n_1$

□ ${}_1n_2 = v_1 / v_2$ □ ${}_1n_2 = n_2 / n_1$

${}_2n_1 = n_1 / n_2 = 1/{}_1n_2$

Snell's law $n_1 \sin\varphi = n_2 \sin\theta$

SAMPLE PROBLEM



Problem : 1 A light ray falls on the surface of glass of absolute refractive index **1.5** with angle of incidence that equal to **30°**. Find **the angle of refraction.**

Solution:

$n_1 \sin\phi = n_2 \sin\theta$ $1 \times \sin 30 = 1.5 \sin\theta$

$\sin\theta = \frac{\sin 30}{1.5} = \frac{0.5}{1.5} = 0.3333$ $\therefore \theta = 19^\circ\ 28'$

Problem : 2

Given that the absolute refractive index for water is **4/3** and that for glass is **3/2**, Find:

a. The relative refractive index from water to glass.

b. The relative refractive index from glass to water.

$_1n_2 = \frac{1}{_2n_1}$

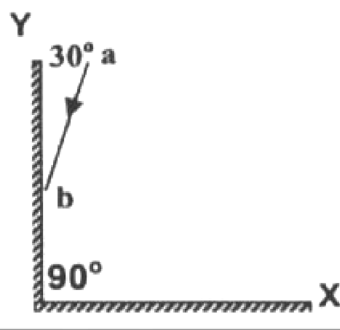
Solution:

a. The relative refractive index from water to glass.

$_wn_g = \frac{n_g}{n_w} = \frac{3}{2} \div \frac{4}{3} = \frac{9}{8}$

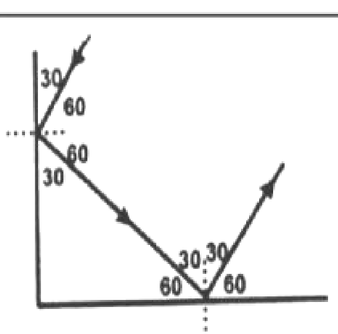
b. The relative refractive index from glass to water.

$_gn_w = \frac{n_w}{n_g} = \frac{4}{3} \div \frac{3}{2} = \frac{8}{9}$



Problem : 3 A ray falls on a mirror (Y), as Shown in the figure **find the angle of reflection at the mirror (y)** complete the drawing. **Determine** the direction of the reflection of the reflected ray at the mirror X.

Solution:



Problem : 4 If the speed of light in the **air 3×10^8 m/sec** and in the glass **2×10^8 m/sec.** Calculate the refractive index (absolute) of glass

Solution:

$_1n_2 = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\sin\phi}{\sin\theta}$ $\frac{n_g}{1} = \frac{3 \times 10^8}{2 \times 10^8}$ $n_g = \frac{3}{2}$

Problem : 5 An incident light ray falls on a surface of glass rectangular block its refractive index **1.5** by an incident angle equal **60°**, calculate the refractive angle

Solution:

$n_1 \sin\phi = n_2 \sin\theta$

$n_{air} \sin 60 = n_g \sin\theta$

$\frac{\sqrt{3}}{2} = 1.5 \sin\theta$ θ = refractive angle = $35^\circ\ 15'\ 52''$

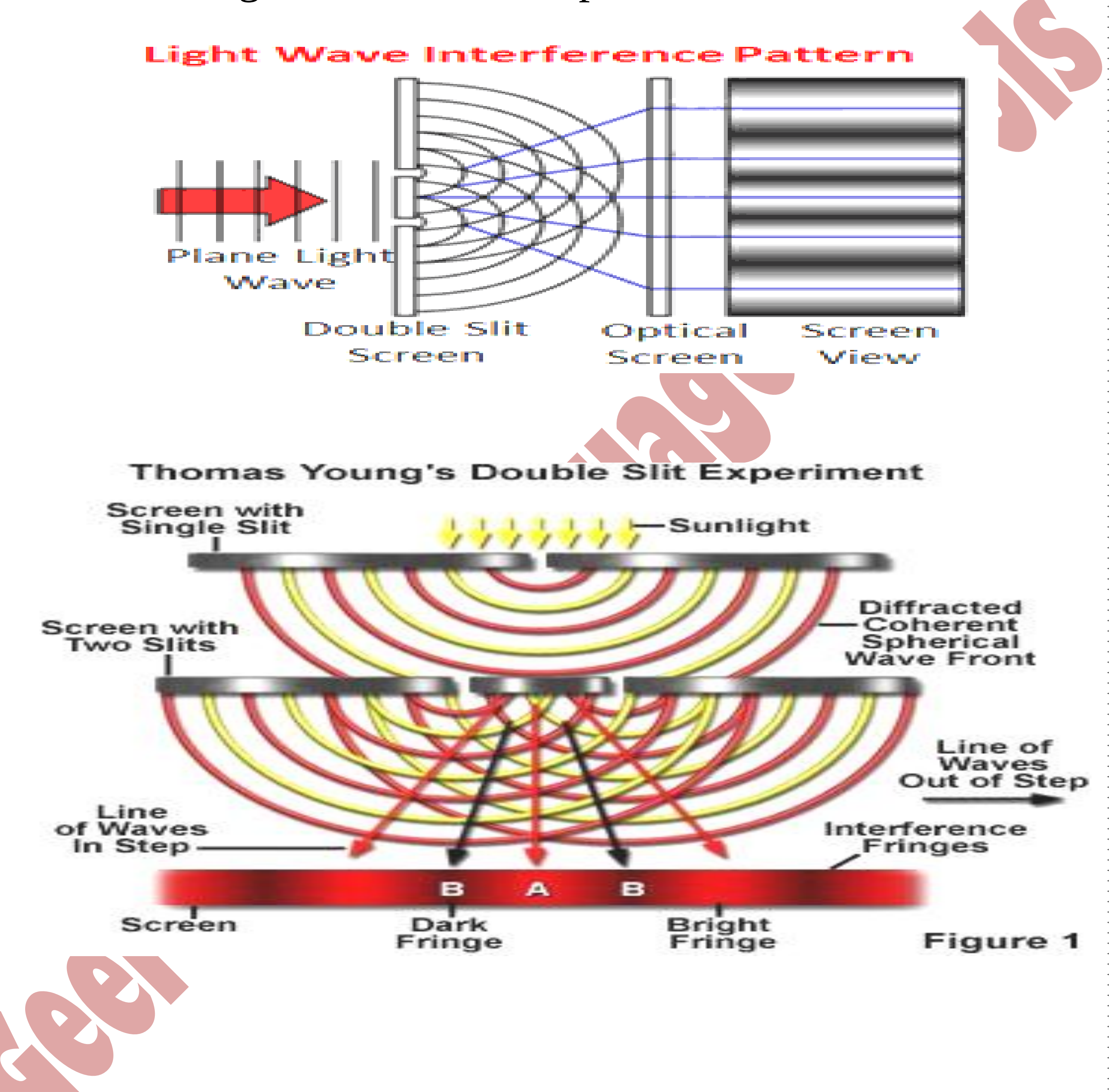
Problem : 6 What is the wavelength of green light wave in the water, given that its wave length in vacuum equals **5600 A^0** and refractive index of water **4/3**?

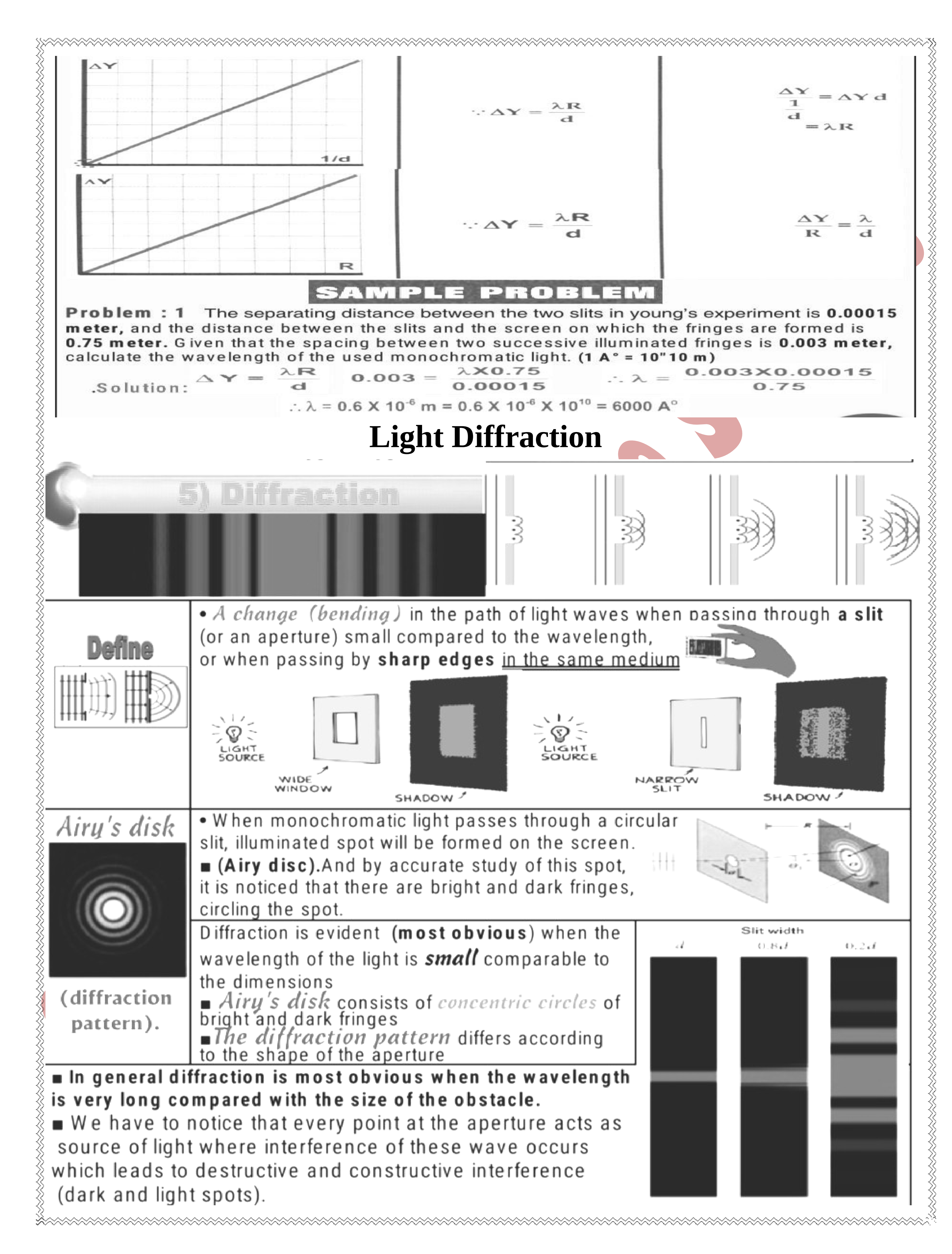
Solution:

$_wn_c = \frac{n_c}{n_w} = \frac{v_w}{v_c} = \frac{\sin\phi}{\sin\theta} = \frac{\lambda_w}{\lambda_c}$ $\frac{n_c}{n_w} = \frac{\lambda_w}{\lambda_c}$ $\frac{1}{3/4} = \frac{\lambda_w}{5600}$ $\lambda_w = 4200\ A^\circ$

L (2) Interference and Diffraction

Thomas Young's double –slit Experiment:





$$\because \Delta Y = \frac{\lambda R}{d}$$

$$\frac{\Delta Y}{\frac{1}{d}} = \Delta Y d = \lambda R$$

$$\because \Delta Y = \frac{\lambda R}{d}$$

$$\frac{\Delta Y}{R} = \frac{\lambda}{d}$$

SAMPLE PROBLEM

Problem : 1 The separating distance between the two slits in young's experiment is **0.00015 meter,** and the distance between the slits and the screen on which the fringes are formed is **0.75 meter.** Given that the spacing between two successive illuminated fringes is **0.003 meter,** calculate the wavelength of the used monochromatic light. **(1 A° = 10"10 m)**

.Solution: $\Delta Y = \frac{\lambda R}{d}$ $\quad 0.003 = \frac{\lambda X 0.75}{0.00015}$ $\quad \therefore \lambda = \frac{0.003 X 0.00015}{0.75}$

$\therefore \lambda = 0.6 \text{ X } 10^{-6}$ m $= 0.6 \text{ X } 10^{-6} \text{ X } 10^{10} = 6000$ A°

Light Diffraction

5) Diffraction

Define

• *A change (bending)* in the path of light waves when passing through **a slit** (or an aperture) small compared to the wavelength, or when passing by **sharp edges** in the same medium

Airy's disk

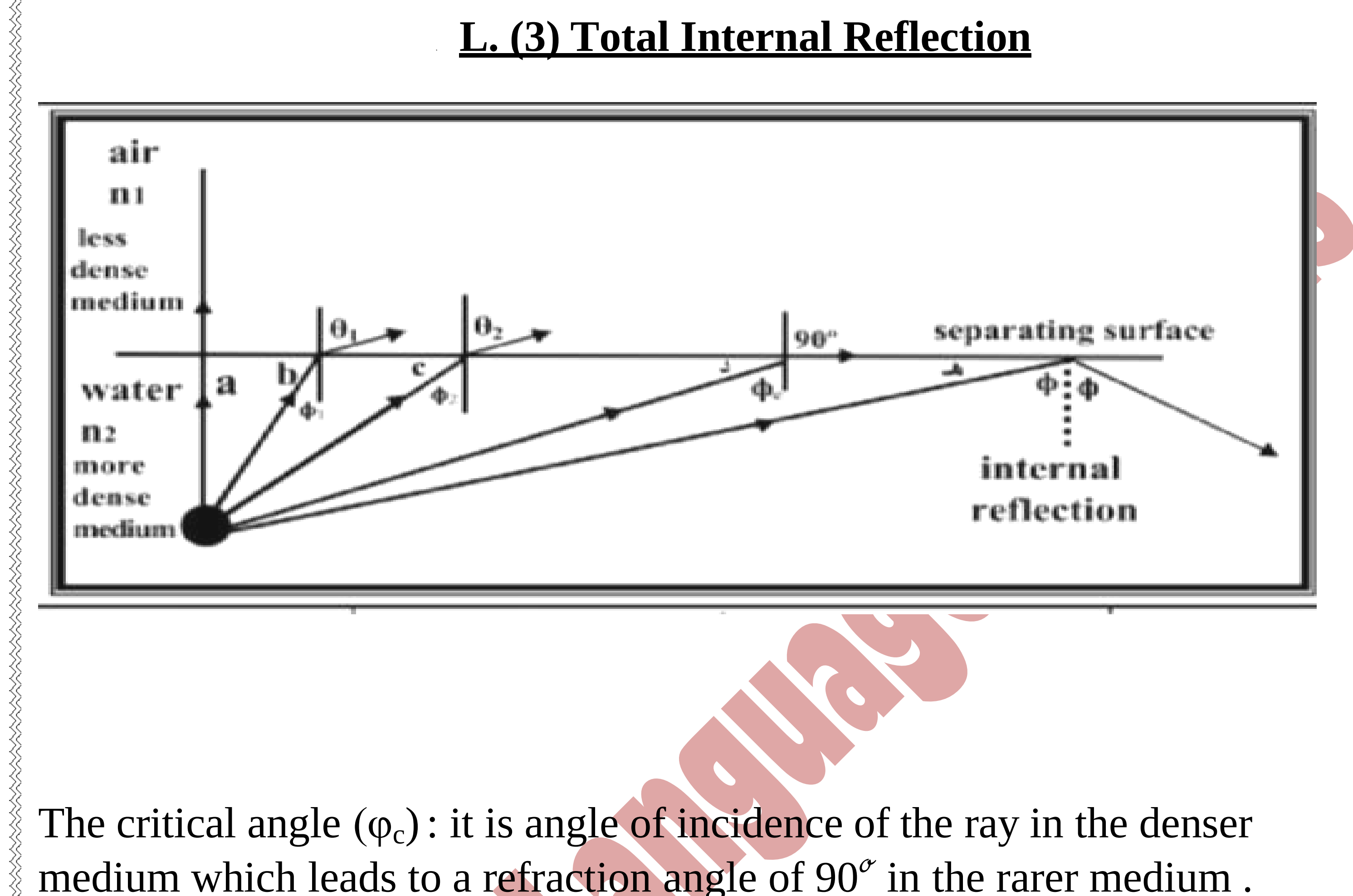
(diffraction pattern).

• When monochromatic light passes through a circular slit, illuminated spot will be formed on the screen.
■ **(Airy disc).**And by accurate study of this spot, it is noticed that there are bright and dark fringes, circling the spot.

Diffraction is evident **(most obvious)** when the wavelength of the light is ***small*** comparable to the dimensions
■ *Airy's disk* consists of *concentric circles* of bright and dark fringes
■ *The diffraction pattern* differs according to the shape of the aperture

■ **In general diffraction is most obvious when the wavelength is very long compared with the size of the obstacle.**
■ We have to notice that every point at the aperture acts as source of light where interference of these wave occurs which leads to destructive and constructive interference (dark and light spots).

L. (3) Total Internal Reflection



The critical angle (φ_c) : it is angle of incidence of the ray in the denser medium which leads to a refraction angle of 90^{o} in the rarer medium .

The critical angle(φ_c) depends on:

1- The type of two media . 2) the wavelength of incident ray.

Deduction of the relation between the critical angle and the refrective index of medium.

$n_1 \sin \varphi = n_2 \sin \theta$

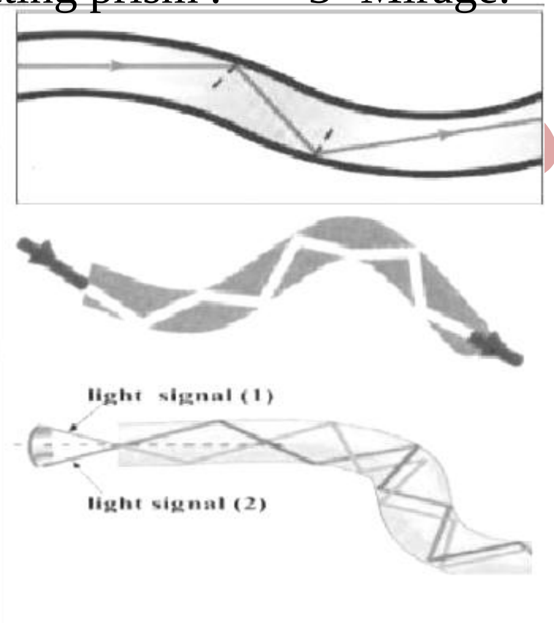
$\Phi = \varphi_c$ and $\theta = 90$

$\text{Sin } \varphi_c = n_2 / n_1 = {}_1n_2$

Application of the total internal reflection:

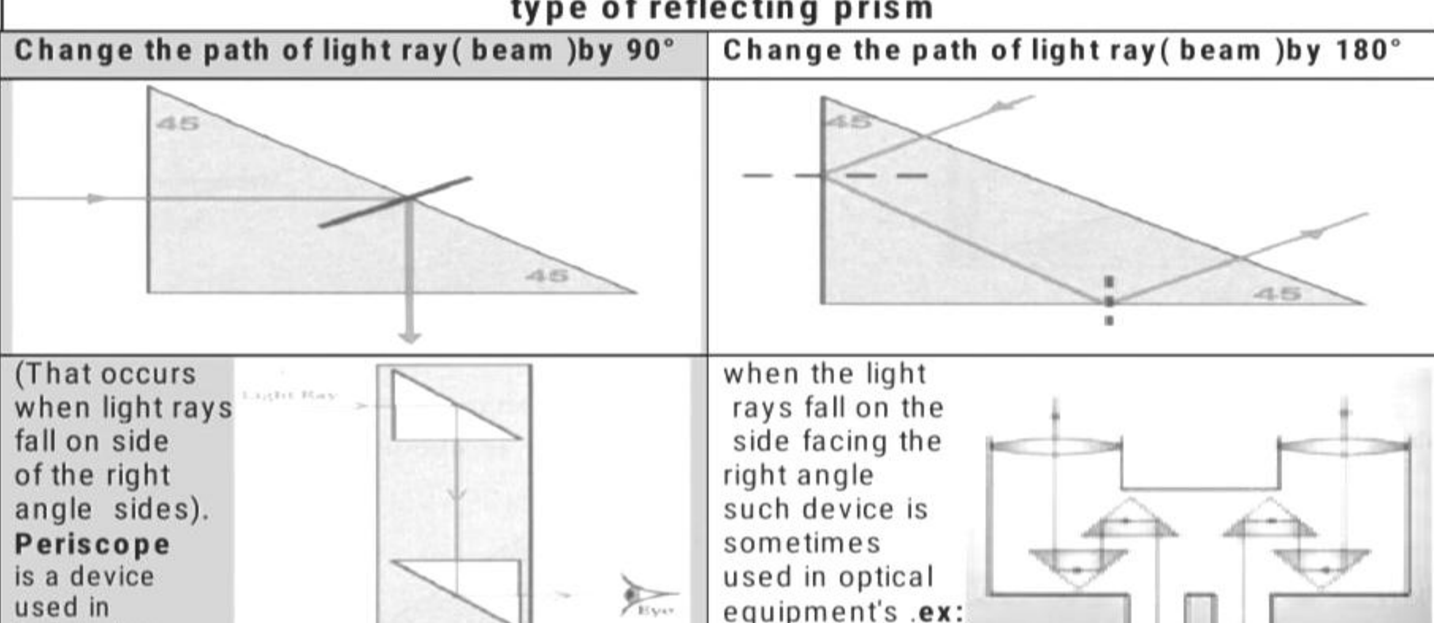
1- Optical fiber (fiberoptics). 2- Reflecting prism . 3- Mirage.

Structure:	• Optical fibers are very thin glass rod. •They are elastic threads of a transparent material • It is a narrow transparent tube
Idea of operation:	**Total internal reflection** Rays entered the rod at one end and these rays allowed to fall with angle greater than the critical angle, these rays suffer from several total internal reflections, until get out from the other end.
Uses:	1. Transporting light energy. *without much loss of light energy* 2. Medical equipment's (endoscopes). *which are used in the diagnosis* 3. In engineering for communication. *used with laser to carry millions of electrical signals*



2) Totally Reflected prisms

• prism **in form of** right angle triangle of glass[**2** equal sides] (**isosceles**)	
• The simplest type of reflecting prism is shown in fig. Its angles are **45°, 45° and 90°.**	
• It is used to change the direction of light ray either by *90°, 180°*	
•The critical angle of glass is ≈ **42°**, if the angle of incidence is > *42°* total reflection takes place	
• prisms are used in **optical instruments** and **medical Equipments**	



type of reflecting prism

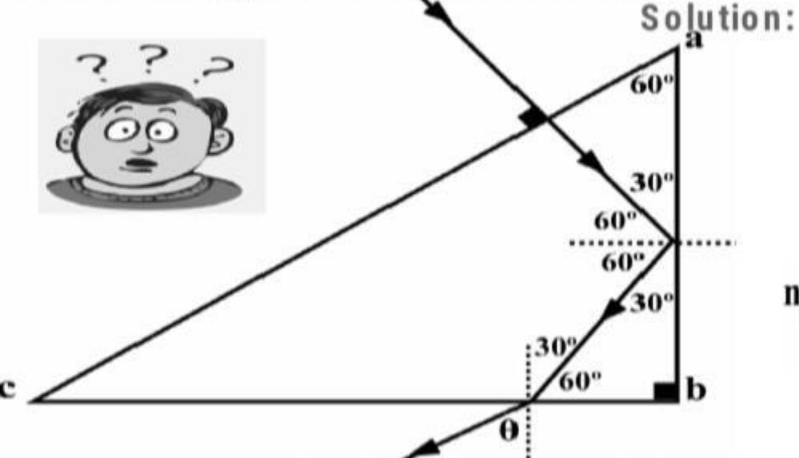
Change the path of light ray(beam)by 90°	Change the path of light ray(beam)by 180°
(That occurs when light rays fall on side of the right angle sides). **Periscope** is a device used in submarines.	when the light rays fall on the side facing the right angle such device is sometimes used in optical equipment's .**ex: A binocular is** used in **fields.**

(Periscope)

Problem : 2 ***(May 99)*** A light ray is incident perpendicular to one of A triangular prism of refractive index 1.5 as shown in figure. Trace the path of the light ray inside the prism in your answer paper then **find its angle of emergence from the prism.**

(Figure: prism abc with angle a = 60°, angle c = 30°, right angle at b)

Solution:



$$\sin \phi_c = \frac{1}{n} = \frac{1}{1.5} = 0.667$$

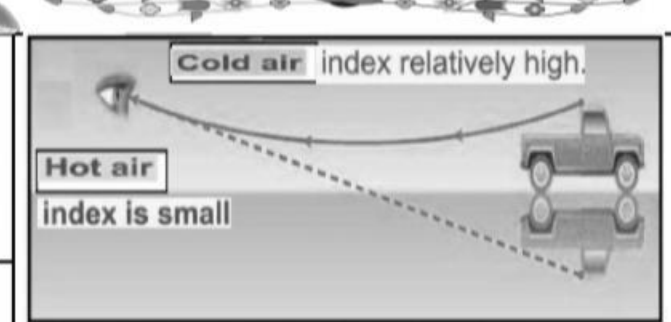
$$\Rightarrow\Rightarrow \therefore \quad \phi_c = 41^\circ.8$$

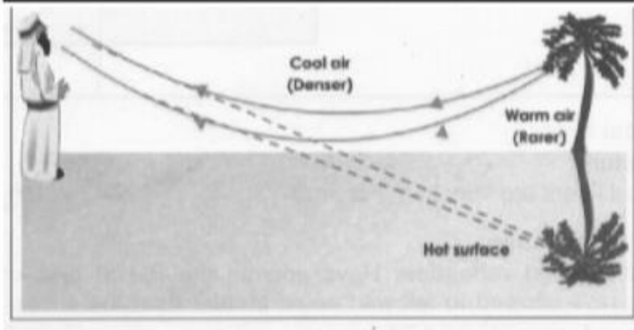
$n_1 \sin \phi = n_2 \sin \theta$ $\quad$ $\therefore 1.5 \sin 30 = 1 \sin\theta$

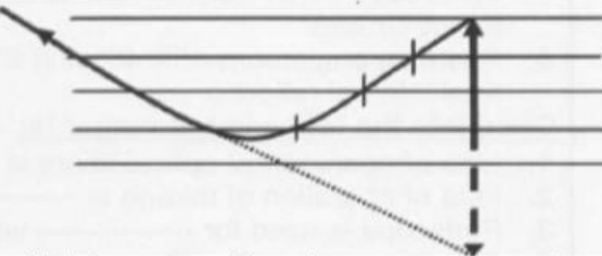
$\therefore \theta = 48^\circ.6$

3) Mirage...

define:	• It is phenomenon of vision of trees or mountains as inverted reflected from surface of water •The mirage is a phenomenon produced by a **total internal reflection,** Where illusive appearance of water in desert.
Condition necessary	•It takes place at noon (midday, very high temp • In high ways or deserts. • air layers nearer the earth surface are very hot and their absolute refractive **index is small.**
occurrence of mirage:	• **1-** upper layers have *low temp* **2-** *Big density* **3-** its (R.I.) (**n**) *becomes greater*
	• **1-** On falling sun rays, the layer of air in contact with earth *become hotter* **2**-they have *low density* **3**-its (R.I.) (**n**) *becomes smaller*
	• When light ray comes from the trees traveling from denser medium (higher layers) to lighter density the **refracted angle increases**
	•If $\varphi > \varphi_c$ *one total internal reflection* take place and we see on the *extension of rays* the bodies reflected and inverted as from water surface







Light ray transfers from upper layer to lower layer refracts away from the normal, **until it falls with angle greater than the critical angle,** *it will totally reflects*.

L.(4) Deviation of Light in a triangular prism

The triangular prism:



• It is made of glass having **5 surfaces**,{ **2 triangles** and **3 rectangles**} .

Rays Through the prism:

When a light ray falls on the surface of a prism, **it refracts twice** and emerges from the other surface, so the ray **deviates** from its original path by an **angle of deviation** (α)

Place the prism on the triangle base and mark position

From the geometry of the fig we find that

1 - Since: **Abec** is quadrilateral

$A + 3 = 180^0$ ---- **(1)** $\quad 3 + \theta_1 + \varphi_2 = 180^0$----(2)

So

the first law of Prism is $A = \theta_1 + \phi_2$

2 - Since:

$\varphi_1 = 1 + \theta_1$(vertically opp) $\quad 1 = \varphi_1 - \theta_1$ ----(1)

$\theta_2 = 2 + \varphi_2$(vertically opp) $\quad 2 = \theta_2 - \varphi_2$ ----(2) α is exterior angle $\quad \alpha = 1 + 2$ -----(3)

$\alpha = (\varphi_1 - \theta_1) + (\theta_2 - \varphi_2)$

$= \varphi_1 + \theta_2 - (\theta_1 + \varphi_2)$ $\quad$ *but* $A = (\theta_1 + \varphi_2)$

2^{nd} law is $\alpha = (\phi_1 + \theta_2) - A$

Name	Symbol	Rule
Angle of the prism	A	$\theta_1 + \phi_2$
Angle of deviation	α	$(\phi_1 + \theta_2) - A$

ab	*it is* the incident ray.	cd	*it is* the emergent ray.
bc	*it is* the refracted ray.	A	*it is* ▪ Angle of the prism ▪ The Apex angle. ▪ Refractive angle
φ_1	*it is* angle of incidence is on the first face.	φ_2	*it is* angle of incidence at the second surface
θ_1	*it is* angle of refraction from the first surface.	θ_2	*it is* angle of emergence

α *it is* **angle of deviation.** ▪ (It is the angle produced between extension of the incident ray and the extension the emergent ray) .

L.(5) Minimum Deviation and Thin prism

Minimum deviation

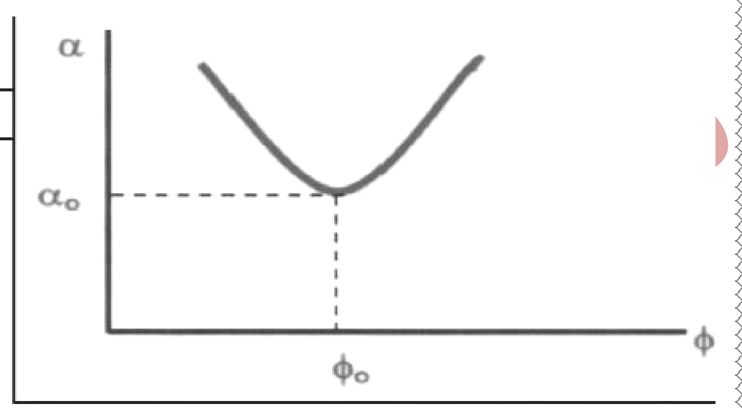


- It is the case in which α **has minimum value** α_o
- and $\varphi_1 = \theta_2$, $\theta_1 = \varphi_2$
- **At minimum deviation :** $\phi_1 = \theta_2 = \phi_0$

Angle of incidence = angle of emergence

At $\theta_1 = \varphi_2$ ---------- $A = \theta_1 + \varphi_2$

$A = \theta_1 + \theta_1 = 2\theta_1$ $\theta_1 = A/2$ ------(1)



- **At minimum deviation :** $\theta_1 = \phi_2 = \theta_o$

Angle of refraction from 1st side = angle of incidence on the 2nd side.

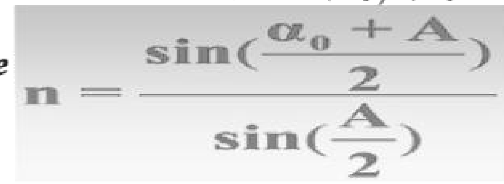
At $\varphi_1 = \theta_2$ -----------$\alpha = \varphi_1 + \theta_2 - A$

$\alpha = \varphi_1 + \varphi_1 - A = 2\varphi_1 - A$

$2\varphi_1 = \alpha + A$------------$\varphi_1 = (\alpha + A)/2$ ------------(2)

Since, $n = \frac{\sin\phi}{\sin\theta}$ *From (1), (2)*

- *refractive index* given by



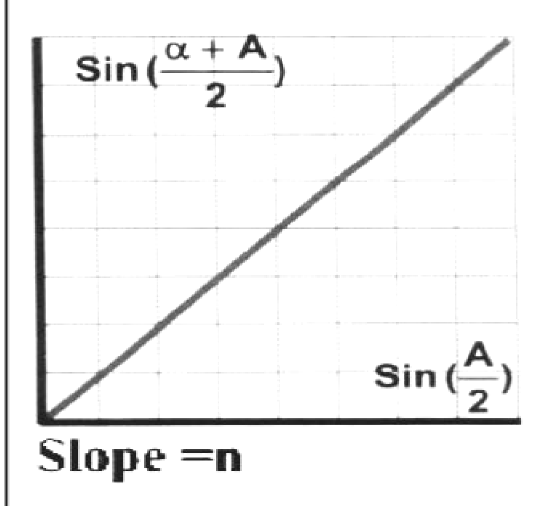
$$n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Factors affecting minimum angle of deviation:

1. **Refractive index (n)** i.e. as the refractive index **increases**, the angle of min deviation **increases** and vice versa
2. **The wavelength** λ

NOTES:

- ✓ *Since (A) is constant for a certain prism*
- ✓ The refractive index depends on *the wavelength*
- ✓ $\frac{n_2}{n_1} = \frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2} = \frac{\sin\phi}{\sin\theta}$
- ✓ So α_o depends on the *wavelength*
- ✓ The white light consists of 7 spectrum colors, each color has its own wavelength.
- ✓ The white light disperses into ***spectrum colors***



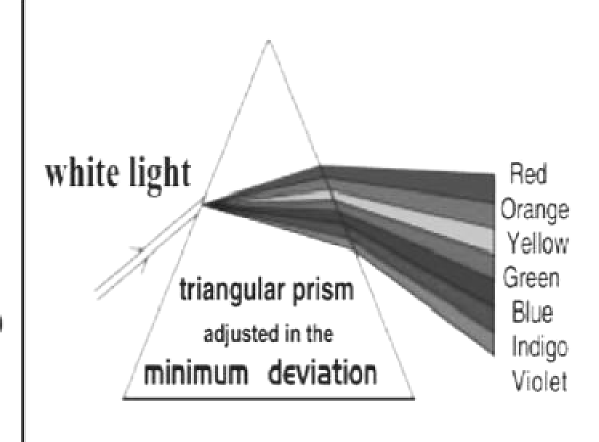
Dispersion of light by prism

when a beam of **white light** falls on a triangular prism, adjusted in the **minimum deviation position** the emerged ray deviated into different color rays **known as**

spectrum

This is because ■different colors have different **refractive indices.**

- Each color has its own **wavelength** and its own **angle of deviation.**



From the previous figure we find that

- **The violet** ray has the **highest deviation** (max. refractive index)
- **The red** ray has the **least deviation** (minimum refraction index)
- Colors of the spectrum of white light are: ***(Roygbiv)***

Red - ***Orange*** - ***Yellow*** - ***Green*** - ***Blue*** - ***Indigo*** - and ***Violet***

Dispersive power (w_α)

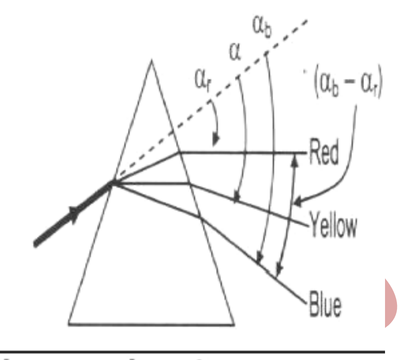
For thin prism: $\alpha_o = A(n-1)$

1-The least deviation occurs for red light: $\alpha_r = A\ (n_r-1)$....... (1)

2-The highest deviation occurs for blue light: $\alpha_b = A\ (n_b-1)$...(2)

3-The mean deviation occurs for yellow light: $\alpha_y = A\ (n_y-1)$...(3)

Refractive index of yellow colors $= n_y = \frac{n_b + n_r}{2}$

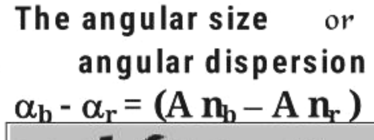


Angular size of dispersion $(\alpha_0)_b - (\alpha_0)_r$

It is **the difference** of angles of minimum deviation of ***blue*** and ***red*** colors in a thin prism.

$(\alpha_0)_b - (\alpha_0)_r = A(n_b - 1) - A(n_r - 1) = A(n_b - 1 - An_r + 1) = (A\,n_b - A\,n_r)$

The angular size *or* **angular dispersion**



$\alpha_b - \alpha_r = (A\,n_b - A\,n_r)$

$= A\,(n_b - n_r)$

Dispersive power ($w\alpha$)

It is **the ratio** between **angular size** and **the** medium **(average) deviation** *It is independent of the apex angle*

$$(\omega) = \frac{\text{Angular size}}{\text{Mean deviation}} = \frac{\alpha_b - \alpha_r}{\alpha_y} = \frac{A(n_b - n_r)}{A(n_y - 1)} = \frac{n_b - n_r}{n_y - 1}$$

$$\omega_\alpha = \frac{\alpha_b - \alpha_r}{\alpha_y} = \frac{n_b - n_r}{n_y - 1}$$

N.B

1-The function of the prism is to **deviate and disperse** light rays

2- <u>The angular size</u> or <u>angular dispersion</u> depends on the **wavelengths** and **refractive indices for colors.**

3- <u>The dispersive power</u> **doesn't** depend on the **angle of the Prism** it is clear From the last equation

where $\alpha_{oy} = \frac{\alpha_{ob} - \alpha_{or}}{2}$ $\quad n_y = \frac{n_b + n_r}{2}$



Unit (2) Chapter (4) L.(1)

Fluid Flow

Hydrodynamics: deals with fluids in motion.

Types of fluid motion

1- Steady flow

The flow of a liquid with small velocity such that its layers slide over each other smoothly.

 The particles of the liquid follow continuous paths (streamlines).

2- Turbulent flow : The liquid can be visualized by a flux of streamlines representing the paths of the different particles of the liquid.

The flow of a liquid when its velocity exceeds a certain limit.

 It is characterized by the existence of vortices.

 Gases undergo turbulent flow as a result of diffusion from a small space to a large space or from high pressure to low pressure.

Streamlines: The paths of the different particles of the liquid during its flow in a tube.

Density of streamlines at a point:

The number of streamlines crossing on unit area around that point.

The properties of the streamlines:

1- Virtual lines don't intersect.

2- The tangent at any point along the streamline determines the direction of the instantaneous velocity at that point.

3- The density of streamlines expresses the velocity of the liquid flow at that point.

4- They become near at points of high velocity and keep apart at points of low velocity.

The conditions of steady flow:

1- The liquid fills the tube completely.

2- The quantity of liquid entering the tube at one end is equal to the quantity of liquid emerging from the other end in the same time (the rate of flow of the liquid is constant along its path).

3- The velocity of the liquid at each point is independent of time .(doesn’t change as time passes.)

4- No frictional forces between the layers of liquid.

The volume rate of flow: (Q_v The volume of the liquid flowing through a cross section of the tube in unit time.

 It’s unit is m^3/s.

 The volume rate of flow

= cross sectional area the distance covered by the liquid in 1 sec. =

cross sectional area the velocity of the liquid

$(Q_v) = v \cdot A$



The mass rate of flow: $Q_{m} = \mathbf{m/t}$

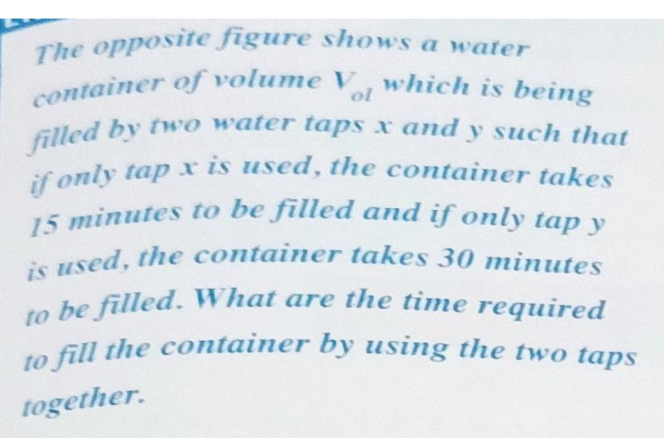
The mass of the liquid flowing through a cross section of the tube in unit time.

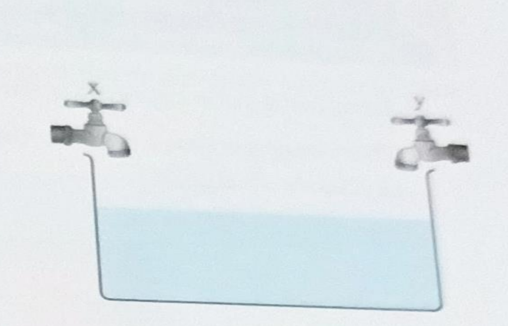
It's unit is kg / s .

The mass rate of flow :

= the volume of the liquid flowing in unit time x liquid density. =

the volume rate of flow x liquid density. = ρ A v = ρ Q_v


The opposite figure shows a water container of volume V_{ol} which is being filled by two water taps x and y such that if only tap x is used, the container takes 15 minutes to be filled and if only tap y is used, the container takes 30 minutes to be filled. What are the time required to fill the container by using the two taps together.



Solution

t_x = 15 minutes | t_y = 30 minutes

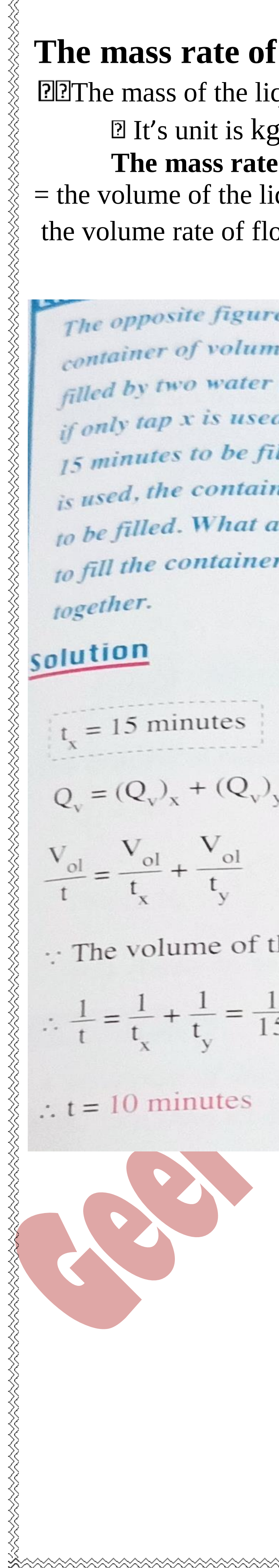
$$Q_v = (Q_v)_x + (Q_v)_y$$

$$\frac{V_{ol}}{t} = \frac{V_{ol}}{t_x} + \frac{V_{ol}}{t_y}$$

$\because$ The volume of the container is fixed.

$$\therefore \frac{1}{t} = \frac{1}{t_x} + \frac{1}{t_y} = \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

$\therefore$ t = 10 minutes



Continuity Equation (**Deduction of the continuity equation between the flow speed of the liquid and the cross section area**)

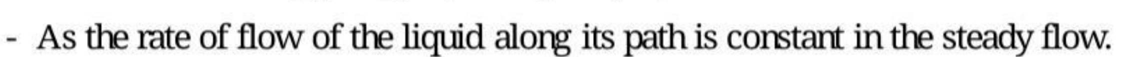
Choose two planes ⊥ to the streamlines at two sections (**a** & **b**).

- The cross sectional areas of the two planes are (A_1 & A_2).
- The velocity of the liquid at the two planes is (V_1 & V_2).
- The mass rate of flow of the liquid through A_1.

$$Q_m = Q_V \times \rho = A_1 \times V_1 \times \rho$$

- The mass rate of flow of the liquid through A_2.

$$Q_m = Q_V \times \rho = A_2 \times V_2 \times \rho$$



- As the rate of flow of the liquid along its path is constant in the steady flow.

$$A_1 \times V_1 \times \rho = A_2 \times V_2 \times \rho$$

$$\boxed{A_1 \times V_1 = A_2 \times V_2} \longrightarrow \text{Continuity equation}$$

$$\boxed{\frac{V_1}{V_2} = \frac{A_2}{A_1}}$$

Continuity equation:

The velocity of the liquid at any point in the tube is inversely proportional to the cross section area of the tube at that point.

❖ The liquid flows slowly where the cross sectional area is large and vice versa.

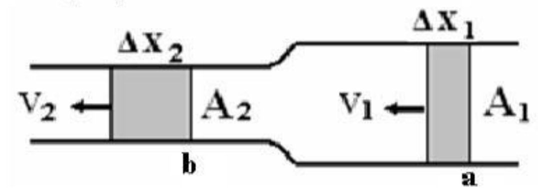
Explaining the continuity equation by the conservation of mass law.

Consider a small amount of liquid ($\Delta m = \rho \Delta V_{ol}$) passes by a point (**a**) with velocity (v_1) and travels a distance (Δx_1) in time (Δt).

❖ The volume that passes in time (Δt).

$\Delta V_{ol} = A_1 \Delta x_1$ where $\Delta x_1 = v_1 \Delta t$

$\therefore \boxed{\Delta V_{ol} = A_1 v_1 \Delta t} \longrightarrow (1)$



❖ Since the liquid is incompressible, the same volume must emerge from the other side of the tube at point (**b**) with velocity (v_2) and travels a distance (Δx_2) in the same time (Δt).

$\Delta V_{ol} = A_2 \Delta x_2$ where $\Delta x_2 = v_2 \Delta t$

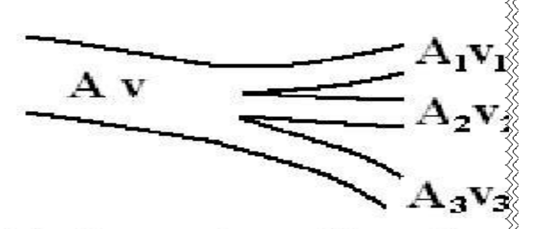
$\therefore \boxed{\Delta V_{ol} = A_2 v_2 \Delta t} \longrightarrow (2)$

❖ From (1) and (2).

$$\therefore \boxed{A_1 v_1 = A_2 v_2}$$

Notes:

1- When a tube is branched into many branches:



$$Q_v = Q_{v1} + Q_{v2} + Q_{v3} + \cdots$$

$$\boxed{A\ v = A_1 v_1 + A_2 v_2 + A_3 v_3 + \cdots}$$

2- If the branches are equal: $A v = n A_1 v_1$, where (n) is the number of branches.

Problems:

Example (1): Water flows in a horizontal pipe by constant rate 0.012m ^{3}/min. Calculate the velocity of water inside the pipe if its cross- sectional area is 1cm ^{2} . **Solution**

$Q_V = Volume / Time = 0.012/60 = 2 \times 10^{-4}\ m^3/sec$

since Qv = A.v = $2 \times 10^{-4} = 1 \times 10^{-4} \times v$

v = 2 m/sec.

Example (2): Water flows through a rubber tube of diameter 2.4 cm with velocity 6m/sec. find the diameter of the narrow open if the velocity of water is 34.56 m / sec.

Solution

$A_1 v_1 = A_2 v_2 = \pi r_1^2 \times v_1 = \pi r_2^2 \times v_2$

$=(0.012)^2 \times 6 = r_2^2 \times 34.56 =$ $r^2_2 = 25 \times 10^{-6}$

$r_2 = 5 \times 10^{-3}$ =m diameter = 10cm.

Example (3): An artery of radius 0.35 is divided to 80 capillaries (each of radius 0.1cm), find the velocity of blood in each capillary , if the velocity of blood in artery is 0.044 m / sec.

Solution

$A_1 v_1 = n A_2 v_2$ $\pi r_1^2 \times v_1 = n \times \pi r_2^2 \times v_2$ $(0.0035)^2 \times 0.044 = 80 \times (0.001)^2 \times v_2$ $v_2 = 0.0067$m/s.

L . (2) Viscosity

Experiment 1- Hang two funnels each on a stand and put a beaker under each.

2- Pour alcohol in one funnel and a similar volume of glycerin in the other.
3- Observe the velocity of each.
Observation: The flow of alcohol is faster than that of glycerin.

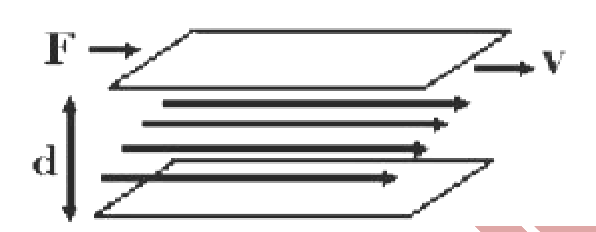
Experiment 2- Take two similar beakers, one containing water and the other containing an equal volume of honey.
2- Stir the liquids in both beakers with a glass rod.
3- Observe which of the liquids is easier to stir.
4- Remove the rod and observe which one stops faster.
Observation: 1- Water is easier to stir (water resistance to the motion of the glass rod is less than that of honey).
2- The motion of honey stops faster than that of water.

Experiment 3- Take two long similar measuring cylinders and fill them to the end, one with water and the other with glycerin.
2- Take two similar steel balls and drop one in each liquid.
3- Record the time each ball takes to hit the bottom.
Observation: The time taken in water is less than that in glycerin (glycerin resistance to the motion of the ball through is greater).

Conclusion: 1- Some liquids such as water and alcohol offer little resistance to the motion of bodies in them; while they can flow easily (**have low viscosity**).
2- Other liquids such as honey and glycerin offer high resistance to the motion of bodies in them; while they don't flow easily (**have high viscosity**).

Viscosity: The property which causes resistance (or friction) between the layers of the liquids hindering the easy sliding of these layers as well as the motion of bodies.

Explaining the viscosity:



- Imagine layers of a liquid trapped two parallel plates, one is stationary and the other is moving with velocity (**v**).

- The liquid layer next to the stationary plate is stationary, while the layer next to the moving plate is moving at (v).

- The layers in between move at velocities varying from (**0**) to (**v**), then.

a) The friction force between the stationary plate and the liquid layer in contact with it due to the adhesive force between the molecules of the solid surface and the contacting liquid molecules lead to zero velocity of this layer. Similarly, the upper layer moves at the same velocity of the moving plate.

b) The friction (shear) force between each liquid layer and the adjacent one resists the sliding of the liquid layers with respect to each other and produces a relative change in velocity between any two adjacent layers.

<u>the viscosity coefficient:</u>

$$F = \eta_{vs} \frac{A\,v}{d}$$

factors affecting the viscosity of coefficient:

1-Type of medium.

2- Temperature of liquid.

- **The measuring units of the coefficient of viscosity:**

1- $\frac{N.m}{m^2 . m/s} = N.s / m^2$

2- $\frac{kg . m/s^2 . m}{m^2 . m/s} = kg.m^{-1}.s^{-1}$

3- $N.s / m^2 = \frac{N}{m^2} s = pascal.s$



Applications of viscosity

1) Lubrication:

The metallic parts of machines are lubricated to;

a. Reduce the heat generated by friction.

b. Protect the machine parts from corrosion (wearing away).

- **Lubrication is carried out using highly viscous liquids.**
  Because they have high adhesive forces, so they remain in contact with the moving parts of machines and reduce friction.

- **Water is not used in lubrication.**
  Because water has low viscosity, so it will seep away from the moving parts of machines due to its low adhesive forces.

- **In summer, lubrication is carried out using very high viscous liquids.**
  Because the viscosity decreases with rising temperature.

2) Economizing fuel consumption in a car:

- Air has resistance on the bodies move in it.
- When a car moves, the work done by the car motor which is supplied from burnt fuel acts against air resistance and friction with the road.

-In medicine ,blood precipitation rate test.

When a ball undergoes a free fall in a liquid ,it is affected by :

Its weight ,friction between ball and the liquid and Buoyancy of the liquid.

In case of anemia the precipitation rate is below normal and in rheumatic fever and gout red blood cells adhere together and precipitation rate increases above the normal.